AFFIDAVIT

I, George D. Geotsalitis do hereby declare as follows:

1. This testimony is being provided solely for the purpose of being used in conjunction with ArrayComm's pending FCC filing, and in no other instance.

2. I am currently Manager of PCS Standards for the United States Cellular Corporation, and have currently held my position for four (4) months.

3. I have more than 22 years of experience in the design and development of telecommunications systems. Previous positions include the following:

   Assistant Director, Standards, Ameritech Cellular
   Manager, Instruction/Development, Bellcore
   Manager, Transmission Engineering, Illinois Bell
   Manager, Technical Planning, Illinois Bell

4. In my current position, I am responsible for participation in the development of standards for PCS.

5. In my capacity as Manager PCS Standards, I have fully reviewed the theoretical and practical basics of ArrayComm's SDMA technology and witnessed a field demonstration thereof.

6. On the basis of my review of the relevant literature and first-hand observations, it is my expert opinion the ArrayComm's SDMA is technically feasible and represents a truly innovative approach to increasing spectral efficiency. Deployment of SDMA technology will substantially reduce the amount of radiated (RF) power (over current technologies) required, per link, to establish reliable communication through directional transmission from and directional transmission by base stations, and will allow multiple wireless links to share the same spectrum in the same cell. The benefits include lower power handsets and base station RF transmissions, and a substantial increase in spectral efficiency. In the context of PCS, deployment of SDMA technology will facilitate more efficient use of available spectrum for all service providers, in addition, to alleviating some of the OFS coexistence issues by substantially reducing contemplated exclusion zones.

Under penalty of perjury, the following is true and correct to the best of my knowledge.

US Cellular Corporation

Name George D. Geotsalitis
Sign George D. Geotsalitis
Title Manager, PCS Standards
Date March 28, 1994

AFFIDAVIT

I, Dennis M. Rucker do hereby declare as follows:

1. This testimony is being provided solely for the purpose of being used in conjunction with ArrayComm's pending FCC filing, and in no other instance.

2. I am currently Director of Engineering for the United States Cellular Corporation, and have currently held my position for nine (9) months.

3. I am a duly qualified engineer, whose qualifications are a matter of record before the Federal Communications Commission. I hold the following degrees:

   BSEE, Purdue, 1972

   I have more than 22 years of experience in the design and development of telecommunications systems. Previous positions include the following:

   Senior Director, Science & Technology, Ameritech Cellular

4. In my current position, I am responsible for supervising the design and installation of cellular telecommunications networks on a nationwide basis.

5. In my capacity as Director of Engineering, I have fully reviewed the theoretical and practical basics of ArrayComm's SDMA technology and witnessed a video taped demonstration thereof, and will be participating in a field demonstration.

6. On the basis of my review of the relevant literature and first-hand observations, it is my expert opinion the ArrayComm's SDMA is technically feasible and represents a truly innovative approach to increasing spectral efficiency. Deployment of SDMA technology will substantially reduce the amount of radiated (RF) power (over current technologies) required, per link, to establish reliable communication through directional transmission from and directional transmission by base stations, and will allow multiple wireless links to share the same spectrum in the same cell. The benefits include lower power handsets and base station RF transmissions, and a substantial increase in spectral efficiency. In the context of PCS, deployment of SDMA technology will facilitate more efficient use of available spectrum for all service providers, in addition, to alleviating some of the OFS coexistence issues by substantially reducing contemplated exclusion zones.

Under penalty of perjury, the following is true and correct to the best of my knowledge.

US Cellular Corporation

Name Dennis M. Rucker

Sign Dennis M Rucker

Title Director of Engineering

Date March 28, 1994

Exhibit 2

SDMA-ENHANCED PCS CELL-SITE ECONOMICS
Cost Per Voice Channel Estimation

	Scenario 1	*Scenario 2*	*Scenario 3*
Cell Configuration			
No. of frequency channels/cell	1	4	8
No. time slots/frequency	7	8	8
Spatial capacity increase factor/time slot	3	3	4
No. of voice channels/cell	21	96	256
Msamples/sec/voice channel	0.04	0.03	0.03
SDMA Processing Power Requirements			
Antenna reuse ratio	0.3	0.3	0.4
No. of antennas	10	10	10
DF updates/sec/frequency	10	10	10
Mflops/DF update/frequency	0.07	0.07	0.08
DF processing speed (Mflops)	20	20	20
No. DF processors required	1	2	3
Vector chip speed (Mflops)	5	5	5
No. of vector chips	1	3	7
Power Amplifier Requirements			
Reference System Design			
Average ERP/voice channel (watts)	7	6	6
Antenna gain/element (dBi)	9	9	9
Antenna cable/coupling loss (dB)	3	3	3
Power combiner output/channel (watts)	2	2	2
Power combiner output (watts)	**37.68**	**150.71**	**401.90**
1 dB compression pt power (watts)	119.15	950.94	4019.02
SDMA Efficiencies w/ PA Linearity			
Total power/total reference power	0.1	0.1	0.1
Power/antenna/total reference power	0.01	0.01	0.01
PA Composite power/1dB compression pt power (dB)	-5	-8	-10
Required PA power/element			
Composite power (watts)	**0.38**	**1.51**	**4.02**
1 dB compression pt power (watts)	1.19	9.51	40.19
Component Costs (large volume)			
Antenna element			
Up converter	$20	$20	$20
Power amplifier	$10	$20	$30
Down converter	$20	$20	$20
Digitizer	$200	$200	$200
Antenna	$50	$50	$50
TOTAL	$300	$310	$320
DF processor chip	$300	$300	$300
Digital filter/decimator	$20	$20	$20
Vector multiplier chip	$20	$20	$20
Digital interpolator	$20	$20	$20
Manufactured cost/component cost			
Antenna system	250%	250%	250%
DF processor boards	1000%	1000%	1000%
Digital receiver/transmitter boards	1000%	1000%	1000%
TOTAL SYSTEM COST			
Antenna subsystem	$7,500	$7,750	$8,000
DF subsystem	$3,000	$6,000	$9,000
Digital receiver subsystem	$4,400	$17,600	$35,200
Digital transmitter subsystem	$1,800	$7,200	$19,200
TOTAL	$16,700	$38,550	$71,400
COST PER VOICE CHANNEL	**$795**	**$402**	**$279**

SDMA-ENHANCED PCS ECONOMICS
Overall Base Station Relative Costs

(Neglecting Recurring Costs)

SDMA System Parameters	Scenario 3A	Scenario 3B
Number of antennas	10	10
Spatial capacity increase factor	4	4
Coverage area increase factor	**4**	**6.5**
Coverage radius increase factor	2.00	2.55
Power loss (1/R^3.85) (dB)	-12.00	-15.00
SDMA processing gain		
Antenna array gain (dB)	10.00	10.00
Interference reduction (dB)	10.00	5.00
TOTAL SDMA Receiver Gain (dB)	20.00	15.00
Net Uplink SINR Improvement (dB)	**8.00**	**0.00**
RF Hardware Related Costs		
Estimated Conventional Cell-Site Cost ($)	$135000.00	$135000.00
Additional Infrastructure Cost/Site ($)	$35000.00	$35000.00
Conventional Base Station RF Costs ($)	$170000.00	$170000.00
Conventional Base Station Cost Multiplier	**4**	**4**
Total cost per Conventional Base Station ($)	$680000.00	$680000.00
SDMA Additional Cost ($)	$71400.00	$71400.00
SDMA related infrastructure costs/site ($)	$40000.00	$40000.00
Total SDMA Additional Costs/Site ($)	$111400.00	$111400.00
Average no. conventional sites eliminated by SDMA	**3**	**5.5**
Fraction of conventional sites required with SDMA	**25.00%**	**15.38%**
SDMA Overall Base Station Relative Cost	**29.10%**	**17.90%**

Scenario 3A: Quality improvement (fixed capacity)
Scenario 3B: Infrastructure complexity reduction (fixed quality)

		Conventional		SDMA	
Urbanization	Total Area	Cell Radius	# of Cells	Cell Radius	# of Cells
City	3080 km^2	0.5 *km*	3922	0.7 *km*	2001
Urban	57750 km^2	1.5 *km*	8170	3.0 *km*	2042
Rural	3224170 km^2	4.0 *km*	5482	10.0 *km*	877
Totals	3285000 km^2		17574		4920
TOTAL COST			$2988M		$1968M

Table 1-1: Cost Advantage of SDMA over Conventional DCS-1800 Systems

Exhibit 3

PC A-TE-v1.4.3

Broadband PCS
Radio Frequency Emissions Proposal
Revision 1.4.3

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1. Introduction

This document proposes rules for limiting the radio frequency (RF) emissions of broadband PCS base stations and mobile units. In the Federal Communications Commission's (FCC) Second Report and Order 93-451 released 22 October 1993, a base station peak power (EIRP) of 100 W per channel and a mobile (handheld) unit peak EIRP of 2 W were adopted.[1] The statement was also made that the intent of the rules was to promote innovation through flexibility (cf. 93-451, section 137, page 56). The changes proposed herein reflect this sentiment. Rather than defining limits on a per carrier/channel basis which allocates more power per hertz to narrower bandwidth channels, all bandwidths are treated equally by allocating power on a per hertz basis. Those with more bandwidth get more power. Subject to the constraint that the maximum possible RF exposure under worst possible conditions be less than currently accepted guidelines, and under the premise that all spectrum should be treated equally in terms of information carrying potential, maximum flexibility is afforded by these proposed limits to allow for a more cost effective roll-out and more timely deployment of PCS systems.

There is no intent in this document to repeat the cogent arguments made in the numerous petitions for increased base station power limits including those of MCI, Telocator (PCIA), Northern Telecom, APC, Ameritech, Motorola, Pacific Bell, U.S. West, and others. Therein, substantial justification for increasing base station powers by over an order of magnitude are presented. Succinct arguments concerning technical aspects (balancing of the forward and reverse links for primary voice service), reduced interference to other fixed services (microwave users), and the substantial economic benefits from higher base station powers are presented. Furthermore, substantive arguments are presented for the introduction of a higher power mobile unit class which we support as well.

[1] The inequities arising from setting limits in terms of a variable quantity, the channel or carrier bandwidth, are clear; narrow bandwidth channels being substantially favored over spread-spectrum technology. Furthermore, RF emissions in excess of the accepted exposure guidelines are allowed under the current proposed rules.

That increased base station transmit power is actually necessary for PCS to compete with cellular service was elegantly stated and substantively supported by Telocator, Northern Telecom and MCI in their filings. Northern also commissioned MLJ to do a study of microwave interference which concluded that higher power limits could actually reduce the interference problem (by giving increased flexibility in site location), and that new advanced antenna technologies were becoming available that could even further reduce the interference problem through intelligent signal processing. ArrayComm has built and successfully tested a prototype of just such a system. Furthermore, these intelligent antenna systems actually lead to reduced RF exposure to the public through directive transmission to and directive reception from mobile units, allowing mobile units to operate at substantially lower powers on average in most applications.

These arguments are so compelling that it is hard to imagine higher base station powers will not be allowed. It is the intent of this document to propose slight alterations to currently accepted definitions of parameters for discussing power limits, and to propose some appropriate limits based thereon. The new definitions facilitate the drafting of rules which manifestly ensure public safety while simultaneously treating operators equally (in proportion to their allocated bandwidth), independent of modulation format. The fundamental principle is that RF exposure guidelines (cf. IEEE C95.1-1991) should determine maximum base station and mobile power limits (cf. 93-451, Section 99.52). Otherwise, subject to noninterference criteria with primary users of the band, operators are given an even playing field upon which to design their systems with maximum flexibility. While not specifically requiring the use of intelligent antenna systems, it is believed that the proposed rules in conjunction with relevant economic analyses will encourage widespread deployment of such systems.

In summary, the rules proposed herein guarantee maximum RF exposure at or below the safe limits set by the ANSI/IEEE guidelines. This is not true of the currently proposed rules (cf. FCC 93-451) under which transmit powers substantially in excess of those deemed safe are allowed. In most practical situations, maximum RF exposure will be less than 1% of the guidelines if the rules proposed herein are adopted.

2. Preliminaries

The intrinsic value of RF spectrum is its information-carrying capacity. This capacity is a function of the power used for signal transmission, the occupied bandwidth, and the distribution of noise power in the band. To ensure that all licensed bandwidths are accorded equitable treatment regardless of chosen modulation format while simultaneously promoting spectral efficiency, rules governing limitations on transmitted power should be expressed in units of power per unit bandwidth. Power limits for a given allocated bandwidth are obtained by simply multiplying by the allocated bandwidth. Thus, independent of modulation format, an operator allocated 20 MHz of spectrum has an aggregate power limit twice (and therefore twice the information carrying capacity) that of an operator with a 10 MHz allocation. Subject to temporal and spatial peak limitations, the operator can distribute this power so as to maximize efficiency throughout his network.

To ensure public safety, the RF emissions from each base station in a given area must be limited in terms of long-term averages over space and time, short-term bursts in time, and concentrations in space (using directive antennas), currently in accordance with IEEE C95.1-1991. These limits should be set in accordance with worst case conditions, i.e., assuming that if directive antennas are employed, all users are in the same location at the same time so that each receives the cumulative field strengths of all base station transmissions as is the case for omni-directional antenna systems. These considerations naturally lead to the necessity for limitations on the peak directional power per unit bandwidth. While use of intelligent antenna systems is not required, antenna systems that can direct power toward users reduce RF exposure to the public compared to current omnidirectional transmission systems by the amount of power gain of the intelligent antenna system assuming a uniform long-term average angular distribution of users.

The issue of interference with other in-band users is beyond the scope of this document. However, any rules developed regarding this issue will overlay those developed for public safety and cooperation at the boundaries of service areas. Since any operational system must meet all of the limitations imposed, operators can meet these specifications by lowering their base station and mobile transmit powers thereby increasing the size of the exclusion zone, or by employing intelligent antennas to ensure noninterference and smaller exclusion zones. The major effect of increasing base station peak directional average radiated power (see definition below) is to increase the coordination radii within which PCS operators must take into account all other users of the band.

3. Definitions

The following definitions are proposed:

Contiguous Service Area (CSA): the contiguous geographic area in which an operator is licensed to use allocated frequency bands for broadband PCS base station emissions.

Base Station (BS): a collection of BST's and BSA's (see below). This definition will coincide with the conventional definition of a base station with the exception of those cases where the operator chooses to operate physically distant power amplifiers in a phase coherent fashion.

Phase Coherent Transmitters: transmitters whose RF carriers are phase-locked as if they were deriving their local oscillators from the same source. Such systems are capable of directing more power into smaller sectors than the sum of individual transmitter output powers. Note that time-synchronous transmission systems which transmit simultaneously from multiple BSA's at different BS's are not necessarily phase coherent since different local oscillators can be employed at each BS.

Base Station Transmitter (BST): one or more RF power amplifiers that operate in overlapping frequency bands in a phase coherent fashion within a CSA.

Base Station Transmitter Average Power (BSTAP): the average RF power produced by a BST over any specified period in units of watts (W). In particular, BSTAP(30) is measured over a 30 minute averaging period. BSTAP(0) is measured over any period of continuous transmission and is the average RF power produced in that interval. Intended for burst mode transmission, BSTAP(0) is measured over the burst interval and is the average radiated power in that interval.

Base Station Antenna (BSA): the combination of all radiating elements connected to a particular BST. BSA's, or portions thereof, may be common to multiple BST's through the use of power combiners or similar devices.

Allocated Frequency Band (AFB): the combined width of the licensee's broadband PCS frequency allocations within a CSA. The units of AFB are hertz (Hz).

Average Radiated Power (ARP): the average base station radiated power in the AFB over any specified period in units of watts (W). In particular, ARP(30) is measured over 30 minute averaging periods. ARP(0) is measured over any period of continuous transmission and is the average radiated power in that interval. Intended for burst mode transmission, ARP(0) is measured over the burst interval and is the average radiated power in that interval. ARP is measured as the sum of the powers delivered to the BSA's from all BST's measured at the BSA connectors.

Average Radiated Power Spectral Density (ARPSD): ARP divided by the AFB in units of watts per hertz (W/Hz). ARPSD(30) is ARP(30) divided by AFB. ARPSD(0) is ARP(0) divided by AFB.

Peak Directional Average Radiated Power (PDARP): the maximum over all directions of the average power radiated in the AFB by all BSA's at a BS in units of watts (W). PDARP(30) is measured over a 30 minute interval. PDARP(0) is measured over any period of continuous transmission and is the average directional radiated power in that interval. Intended for burst mode transmission, PDARP(0) is measured over the burst interval and is the peak directional average radiated power in that interval. PDARP can be calculated by first determining the gain of the BSA (with respect to an ideal omnidirectional antenna) corresponding to each BST for all values of azimuth and elevation (N.B. for the purposes of this calculation, if a BSA is shared by multiple BST's, each BST is treated as though it had an independent identical copy of the BSA). Next, the gain pattern for each BSA is multiplied by the BSTAP for its corresponding

BST, yielding radiated power as a function of direction in units of watts. PDARP is the maximum over all azimuth and elevation values of the sum of these power patterns.

PDARP may be measured by use of a (RF) power meter and a probe antenna, although it will only be accurate for line-of-sight unobstructed paths. Measuring the power in the AFB and dividing by the measurement antenna's effective area yields a measured power per unit area. Multiplying this by the square of the distance from the BSA gives the radiation intensity in power per steradian.[1] Multiplying the radiation intensity by 4π yields the measured PDARP.

Peak Directional Average Radiated Power Spectral Density (PDARPSD): PDARP divided by the AFB in units of watts per hertz (W/Hz). PDARPSD(30) is PDARP(30) divided by AFB. PDARPSD(0) is PDARP(0) divided by AFB.

Subscriber Radio Equipment (SRE): SRE is the radio equipment used by a PCS subscriber to communicate with one or more BS's.

Subscriber PDARP (SPDARP): the maximum over all directions of the average RF power radiated by an SRE in units of watts (W). SPDARP(2) is measured over a 2 minute interval. Intended for burst mode transmission, SPDARP(0) is measured over the burst interval and is the peak directional average radiated power in that interval.

Minimum Safe Distance (MSD): The minimum safe distance between a person and a BS/BSA/BST as determined from the criteria set forth in IEEE C95.1-1991 which is a function of PDARP(30).

4. Proposed Broadband PCS Transmitter Power Limitations

4.1 Peak Directional Average Radiated Power Spectral Density Limits

Base station Peak Directional Average Radiated Power Spectral Density PDARPSD(30) shall be limited as a function of BSA height above ground (HAG) according to the following formula:

$$\text{PDARPSD(30) in (mW/Hz)} = \begin{cases} 4\pi S h^2/\text{AFB}_{total}; & h \leq 100 \text{ meters}, \\ 13.6; & h > 100 \text{ meters}. \end{cases}$$

where

$$h = \text{antenna height above ground in meters},$$

[1] A steradian is the dimensionless unit of solid angle which is one radian on a side.

$S = f/0.15$: ANSI exposure limit in mW/m^2,

$f = 1950$: center frequency in MHz,

$AFB_{total} = 120\ MHz$; the total PCS allocation,

and PDARPSD(0) shall be limited to 10 times PDARPSD(30). The following table is obtained directly from the formula:

Antenna HAC (m)	Maximum PDARPSD(30) (mW/Hz)	Maximum PDARPSD(0) (mW/Hz)
10	0.14	1.4
20	0.54	5.4
50	3.40	34.0
≥100	13.60	136.0

4.2 Average Radiated Power Spectral Density Limits

Base station Average Radiated Power Spectral Density ARPSD(30) shall be limited as a function of BSA HAG according to the following formula:

$$\text{ARPSD(30) in (mW/Hz)} = \begin{cases} \text{PDARPSD(30)/100;} & h \geq 10 \text{ meters,} \\ 0.0014; & h < 10 \text{ meters,} \end{cases}$$

and ARPSD(0) shall be limited to 10 times ARPSD(30). The following table is obtained directly from the formula:

Antenna HAG (m)	Maximum ARPSD(30) (mW/Hz)	Maximum ARPSD(0) (mW/Hz)
≤ 10	0.0014	0.014
20	0.0054	0.054
50	0.0340	0.340
≥100	0.1360	1.360

4.3 Field Strength Limits

The predicted or measured median field strength at any location on the border of the PCS service area shall not exceed 47 dBuV/m unless the parties agree to a higher field strength (cf. Section 99.232, Appendix A, Second Report and Order).

4.4 Interference Protection

No changes to the interference protection rule given in Section 99.232, Appendix A, Second Report and Order as amended are recommended at this time.

4.5 Mobile Power Limits

Handheld mobile unit powers shall not exceed 2 W SPDARP(0). A second class of mobile unit is permitted which subject to a minimum distance of 0.8 meters from user to antenna, is subject to a 12 W SPDARP(2) limitation, and a 120 W SPDARP(0) limitation. Note that the minimum safe distance at 2 GHz for a 120 W transmitter is 0.8 meters assuming it is "uncontrolled".

5. Discussion

5.1 Safety Considerations

The power limits were derived from calculations of ANSI standard RF exposure limits as a function of frequency uncontrolled environments. The following assumptions were made:

1. the entire 120 MHz band is active at maximum power,
2. the antenna height above ground (HAG) is equal to the minimum boresight approach distance, and
3. safe peak (or burst mode) powers (see discussion on peak power below) are no less than 10 times the long-term average power limits in uncontrolled environments.

With these assumptions, power limits for base station transmissions are calculated directly from the RF exposure guidelines in IEEE C95.1-1991 and Appendix E: Compliance with ANSI/IEEE RF Guidelines, FCC 93-451, Second Report and Order. The power limits are then converted to units of W/Hz by dividing by the total frequency allocation of 120 MHz.

The first assumption is directed toward worst case analysis since it requires all (seven (7)) operators to operate from the same location, and have all their channels simultaneously active "in the same direction" at maximum power. Note that if omnidirectional or low-gain antennas are used, then the limitation on total average radiated power (ARP(30)) will limit the worst case exposure even further.[1] Note that while the peak directive power in the absolute worst case is given by the safe exposure limit, the total average radiated power is a factor of 100 smaller (at least) than this. Practically, however, this power is largely concentrated in the horizontal dimension for cellular systems. Statistically, therefore, this means that the maximum average exposure over random user distributions is ARP(30) which for antenna heights greater than 10 meters is less than 1/10 of the safe exposure limits. In summary, in the worst possible case, maximum RF exposure below or at the safe limits set by the ANSI/IEEE guidelines is guaranteed. In most practical situations, average RF exposure will be less than 10% of the safe limits (for higher antenna base stations) when the

[1] If the antenna gain G is less than 100, then the worst case PDARP will be $G/100$ times the allowable limit for antennas above 10 meters height. A 10 dB horizontal omni monopole antenna will only be allowed to transmit 1/10 the PDARP(30) limit.

base station is fully loaded. Using a daily loading factor of 30%, and a reuse factor of at least 3, the average exposure drops to less than 1% of the guidelines.

With regard to the second assumption, in situations where boresight minimum approach distances less than the antenna HAG are possible, the power limits should be adjusted accordingly. Furthermore, relief from the height limitations should be considered in situations where substantially larger boresight minimum approach distances can be guaranteed. As a practical matter, boresight minimum approach distances less than the typical height of an antenna above the surrounding terrain will be unattainable by the public (even to within a factor of 2 or 3 in distance). The limits proposed for PDARPSD(30) are therefore quite conservative in light of the guidelines.

5.2 PDARP and EIRP

In essence, PDARP is obtained by divorcing the concept of channel bandwidth from the more conventional concept of EIRP. For a single-sector system employing BSA's with static gain patterns, PDARP is simply the sum of the per-channel EIRP's. In systems employing BSA's with dynamic gain patterns, PDARP's will depend on user densities, exclusion zones and other parameters. The use of multiple transmitting elements per channel is relatively new, although it is employed in the GSM systems of several manufacturers.

Note also that under the current rules where peak EIRP's of 100 W per channel are allowed, it is possible, employing 5 kHz channels in a 30 MHz allocation, to transmit 600 kW EIRP over the entire band. Furthermore, the allowed power is inversely proportional to the channel bandwidth, thus allowing transmit powers well in excess of the ANSI/IEEE safe limit. On the other hand, the rules proposed herein limit the total exposure to the safe limit which in this case is 408 kW at the maximum antenna height (minimum boresight approach distance). Note that under the current proposed rules, the 600 kW PDARP is allowed for all antenna heights below 300 meters, including those at 10 meters! Under the proposed rules, antennas at 10 meters would be limited to 4 kW PDARP.

5.3 ARP, PDARP, Antenna Gain and Peak Power

The concepts of ARP and PDARP are similar as mentioned earlier to total radiated power and EIRP respectively. In particular, for a fixed-gain antenna, PDARP/ARP is the peak antenna gain in dBi. The omnidirectional reference is a consequence of defining ARP as nondirectional, i.e., with respect to an omnidirectional antenna. The ratio of the limits of these quantities varies from 1 to 100 as the antenna height increases. For low antenna heights, the probability of incidental physical contact is greater, so peak directional power is ultimately reduced to 1 times the average. For BSA's at greater heights, gains of 100 (or 20dB) are used. The choice of 20 dB was made on practical technical and economic bases; antennas with gains approaching 20 dB can be purchased and operated at reasonable cost.

The definition of ARP(0) is intended to address the time-domain analog of spatial focusing, that of temporal focusing. In systems employing burst mode (on-off) transmission, long-term average can power differ from short-term or peak power by the ratio of the burst duration to the interval between bursts, i.e., the ratio of on-time to on-time plus off-time. The limit on ARP(0) determines the allowable concentration of power in the time domain without loss of information carrying capacity, i.e., at constant long-term average power. The factor of 10 dB between ARP(0) and ARP(30) sets the lossless concentration factor to 10, i.e., 10% duty cycle, so that 10 times the long-term average power is allowed, but only 10% of the time. This factor of 10 in power implies that peak (short-term average) field strengths 3 times larger than the long-term average field strengths are allowed. Note that the long-term average power is unchanged. This peak-to-average (or short-term-to-long-term average) power ratio could be modified to be consistent with RF exposure limits presumably derived from experimental data as they become available.

5.4 Sample PCS Calculations

For 30 MHz PCS allocations, the maximum ARPSD(30) for antenna heights of 50 meters corresponds to a 1.0 kilowatt (kW) limit on the power radiated by a base station. For example, assuming an antenna with 22 dBi gain (G=160), this 1.0 kW would support 100 1.6 kW EIRP carriers.[2] However, the PDARPSD(30) limit corresponds to a base station peak directional average radiated power limit of 100 kW. This accommodates only 62 1.6 kW EIRP carriers, which is therefore the limit in this case.

Note that this calculation is entirely channel bandwidth independent and therefore applies to any air interface. For example, there are 75 200 kHz paired channels in a 30 MHz allocation. If all channels carry 8 traffic channels such as PCS-1900, an omni cell with a 20 dBi gain antenna at least 54 meters (1.2 kW ARP(30) limit) above ground could handle 600 simultaneous links at 1.6 kW peak EIRP each. The average EIRP per traffic channel is 1600/8 = 200 W.

There are also 6 5 MHz channels in the 30 MHz allocation, which will handle approximately 200 simultaneous links if each channel carries 32 time-division duplex traffic channels. For an omni cell with a 20 dBi gain antenna at least 54 meters (1.2 kW ARP(30) limit) above ground, and assuming a 50% transmit duty cycle to achieve full-duplex operation, all traffic channels could transmit 40 kW peak EIRP each (120 kW PDARP / 6 channels / 50% duty cycle). In this case the average EIRP per traffic channel is 40/64 = 600 W.

As a final example, there are 12 1.25 MHz paired channels in a 30 MHz allocation. If all channels carry 64 traffic channels (neglecting control channels) such as IS-95 CDMA-based systems, an omni cell with a 20 dBi gain antenna at least 54 meters above ground could handle 768 simultaneous links at 156 W (peak/average) EIRP each.

In each of these examples, the average power per channel is inversely related to the number of channels, and the product is fixed at the maximum allowable (safe) transmit

[2] Note that this link happens to be approximately balanced by a 2 W EIRP mobile unit assuming a 200 kHz channel bandwidth per carrier and nominal values for base station receiver diversity gain and receiver sensitivities (cf., the Telocator Petition for Reconsideration).

power. This simplistic discussion does not take into account frequency reuse, interference analysis, RF propagation and related cell sizes/coverage areas, or any other similar effects. These only serve to decrease the number of channels practically usable at each base station.

5.5 Balanced Links

It is also important to note that balanced links are not a requirement for PCS operation. Furthermore, balanced links should neither be imposed, nor be used as rationale for reducing base station power limits. There is a demonstrated market (e.g., paging and short-message services) for higher data rate one-way services which can benefit substantially from higher downlink EIRP's. Such service should not be precluded while the public is in no danger of RF exposure in excess of accepted limits.

5.6 Mobile Power Limits

The commission has adopted a 2 W peak EIRP[3] which is retained. It is currently general practice to have handhelds with continuous transmission of 1 W EIRP (0.6 W transmitter into a 2 dBi dipole antenna) as in the AMPS system today. Reflecting the increased RF transmission loss at 2 GHz, a 2 W limit seems to be appropriate (from an economic viewpoint).

It should be noted, however, that the absence of a limit on long-term average power treats mobile users unequally depending upon the particular modulation format. Under these rules, an analog FM mobile user has 6 times the information carrying capacity of a 6-slot TDMA mobile user in the same RF bandwidth. To be equitable in this case, 6-slot TDMA mobile users should be allowed the same time average power as analog FM user. A 6-slot TDMA mobile should be allowed peak powers 6 times greater than the average analog FM power, assuming that such powers are within yet to be adopted exposure guidelines for handheld units at 2 GHz in controlled environments. When such guidelines are adopted, we would recommend revisiting this issue.

Finally, as indicated above, the minimum safe distance at 2 GHz for a 120 W transmitter is 0.8 meters assuming it is "uncontrolled". Therefore, in terms of average exposure, even the new class of mobile with 12 W SPDARP(2) is quite conservative.

[3]In terms of the definitions contained herein, mobile unit peak EIRP is SPDARP(0).

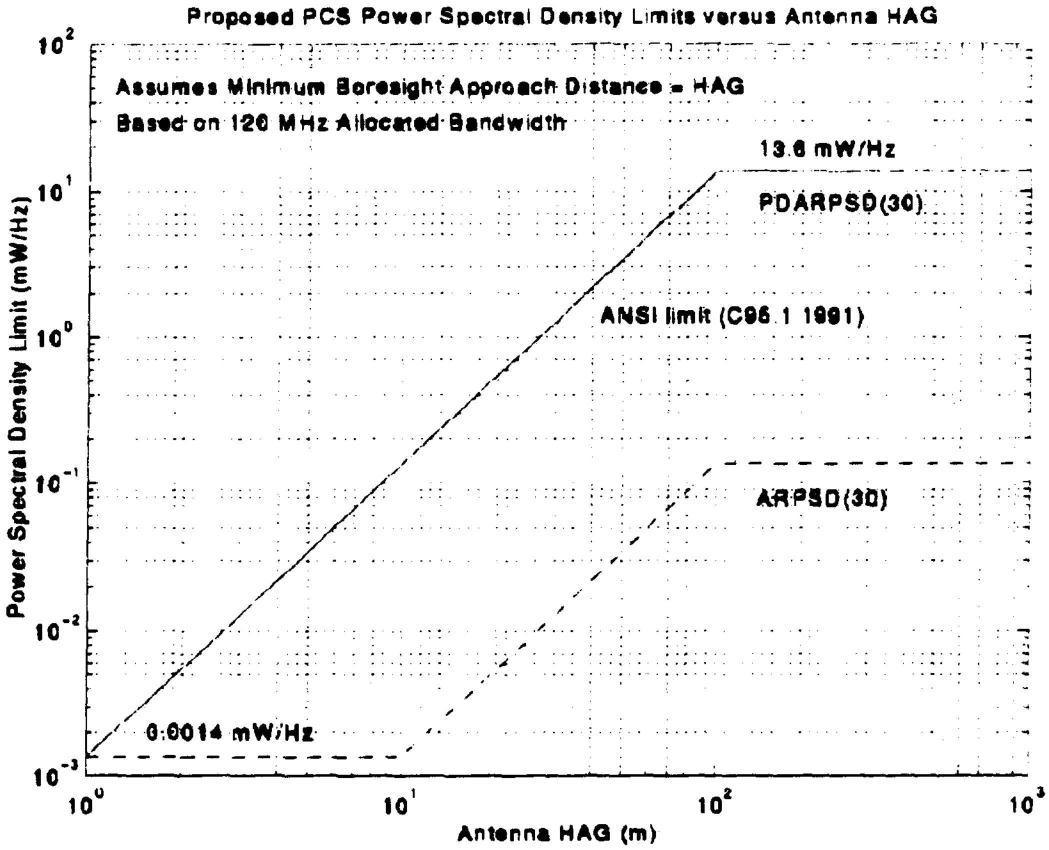

Figure 5-1: PCS Power Limits versus Antenna Height Based on IEEE C.95-1 1991 RF Exposure Limits at 2 GHz

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FOR IMMEDIATE RELEASE

CALIFORNIA CONSORTIUM WINS GOVERNMENT MATCHING GRANT TO COMMERCIALIZE COST-SAVING WIRELESS TECHNOLOGY

Santa Clara, Calif. (March 3, 1994) -- A consortium of three California companies has been awarded a government matching grant to enter the high stakes international race to commercialize a wireless technology that will help make personal communications systems (PCS) widely available at a cost equal to or lower than that of present home telephone service.

The companies, ArrayComm, Inc., of Santa Clara, Watkins-Johnson Company of Palo Alto, and Spectrian, Inc., of Mountain View learned last week (Feb. 24) that the Defense Department's Advanced Research Projects Agency (ARPA) had awarded the matching grant in an $11.4 million effort to create "smart antenna" technology for the global wireless communications market. The grant is part of a government program to help strengthen the economy and enhance international competitiveness by converting defense technology to commercial use.

PCS will enable people to use small wireless communications devices anywhere for voice, data or image transmission, including faxing, messaging and computer-to-computer communications. The market for PCS related products and services is expected to reach $200 billion by early in the next decade. More than 50 countries plan to establish wireless telephone systems. In the last quarter of 1994, the Federal Communications Commission is expected to auction PCS licenses in the U.S., and bids are expected from the RBOC's, long-distance telephone companies, and cable operators, among others.

"It has been my dream to see wireless phones available to everyone," said Martin Cooper, Chairman and CEO of ArrayComm, a pioneer in the personal communications industry and widely regarded as the "father" of cellular telephony. "Our intelligent electronic antennas will bring that dream one step closer to reality. The ultimate winners of the PCS race will be the players who can commercialize an efficient, cost effective product. Aided by this grant, our technology will make a vital contribution to this endeavor."

- more -

Under the grant, the consortium will develop a prototype that will implement ArrayComm's patented Spatial Division Multiple Access (SDMA) technology, a technology that can enhance all of the analog and digital standards being considered world-wide.

A NEW CONCEPT IN RADIO SIGNAL PROCESSING

ArrayComm's proprietary breakthrough SDMA technology exploits new concepts in spatial signal processing to create directional communication links. Through this technology, small arrays of conventional antennas can be used to track mobile units and receive and transmit voice, data and pictures more efficiently.

"The result," according to Mr. Cooper, "will be greater coverage, system capacity, and efficiency, and clearer communications signals. This technology addresses problems with existing systems such as poor reception, cross talk, and dropped calls. Moreover, we believe that SDMA will make possible the manufacture of smaller, lighter, less-costly handsets with longer battery life."

Mr. Cooper pointed out that, "preliminary calculations for deployment of PCS systems using this technology indicate a system cost-savings of 30% or more."

RANGE OF APPLICATIONS

SDMA is compatible with analog or digital, existing or planned, wireless systems. In addition to PCS, SDMA technology will have applications in: cellular mobile communications systems; wireless mobile data; paging and wireless electronic messaging; personal digital assistant communication systems; wireless local loops; and air-to-ground telephone and satellite communications systems. The technology also has potential in government applications like law enforcement and intelligence.

ArrayComm will provide the system architecture and software for the signal processing in the project. Spectrian will provide its state-of-the-art power amplification technology, and Watkins-Johnson's Communications Electronics Division will have a range of responsibilities, including provision of receiver technology.

- more -

In its application, the consortium requested a $5,590,000 grant from ARPA, to be matched by $2,250,000 from ArrayComm, $1,929,000 by Watkins-Johnson, and $1,625,000 by Spectrian. Once work begins, the project is to be completed in 24 months.

"I am excited about this award for two reasons. First, the joint efforts of the team members will lead to a tangible product which promises to advance wireless communications technology. Further, the program provides an avenue of contribution for people previously engaged primarily in the development of military products," said Keith Kennedy, President and CEO of Watkins-Johnson Company.

TECHNOLOGY REINVESTMENT PROJECT

The Technology Reinvestment Project (TRP) is part of the Clinton Administration initiative to increase American employment and competitiveness in the commercial sector by reapplying technologies, skilled manpower and resources originally intended for the military. ARPA administers the TRP, which had a $554 million budget in fiscal year 1994 and is to have a $625 million budget in fiscal year 1995.

NEW HIGH-TECH JOBS IN CALIFORNIA

Commenting on the project, Woody Rea, President and CEO of Spectrian, said, "this grant and collaboration among our companies will bring together significant expertise and accelerate the technology developments necessary to make low cost PCS a reality. While the emerging PCS marketplace requires many of the fundamental technologies of today's conventional cellular, they will have to be substantially enhanced and retooled to support lower cost architecture necessary for successful deployment. A result will be the creation of new high-tech jobs, a key goal of the TRP."

As a result of this project, the consortium expects to create more than 300 new jobs in the San Francisco Bay Area as development progresses and manufacturing begins, according to Mr. Cooper. ArrayComm expects to double in size by the end of 1994.

ArrayComm, Inc., was founded in 1992 by scientists, engineers, and managers from the telecommunications industry to develop commercial applications for breakthrough algorithms in array signal processing invented by Dr. Richard Roy and co-workers at Stanford University. Dr. Roy is President of ArrayComm, which has 16 employees. The company holds patents and has patents pending for its SDMA technology.

- more -

Founded in 1957, Watkins-Johnson Company (NYSE:WJ) is a diversified corporation specializing in electronics products, semiconductor-manufacturing equipment and environmental consulting services. The company employs 2,400 people in six locations. Sales in 1993 exceeded $286 million. The company's Communications Electronics Division, Gaithersburg, MD, specializes in communications receiving equipment and has been a supplier to the Department of Defense and international customers.

Spectrian was founded in 1984 and developed a significant portfolio RF power amplification technology primarily on defense contracts during the 1980's. Over the last three years, the company has completed a transition to become a commercial supplier of leading edge technology to the cellular telecommunications industry. Its enabling products provide ultra-linear capabilities necessary for emerging PCS systems. Located in Mountain View, CA, the company employees 330 people.

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AFFIDAVIT

I, Richard Roy, hereby declare as follows:

1) I am President and Chief Technical Officer of ArrayComm, Inc. and President and Chief Technical Officer of Spatial Communications, Inc.

2) I have reviewed the foregoing comments. The attached technical exhibit was prepared under my supervision. The foregoing comments and technical exhibit are true and correct to the best of my knowledge and belief.

Richard Roy

Dr. Richard Roy
ArrayComm, Inc.
Spatial Communications, Inc.